National Aeronautics and Space Administration

NASA's Deep Space Network (DSN) Lunar Exploration Upgrades (DLEU)

Philip Baldwin (Presenter) - NASA
Greg Heckler – NASA
Brad Arnold – JPL
Jeff Berner – JPL
Erica Weir – Teltrium
Allison McCarthy - Teltrium

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Outline

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- DSN Network
- DSN Overview –
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  - Mission types
  - Frequency bands
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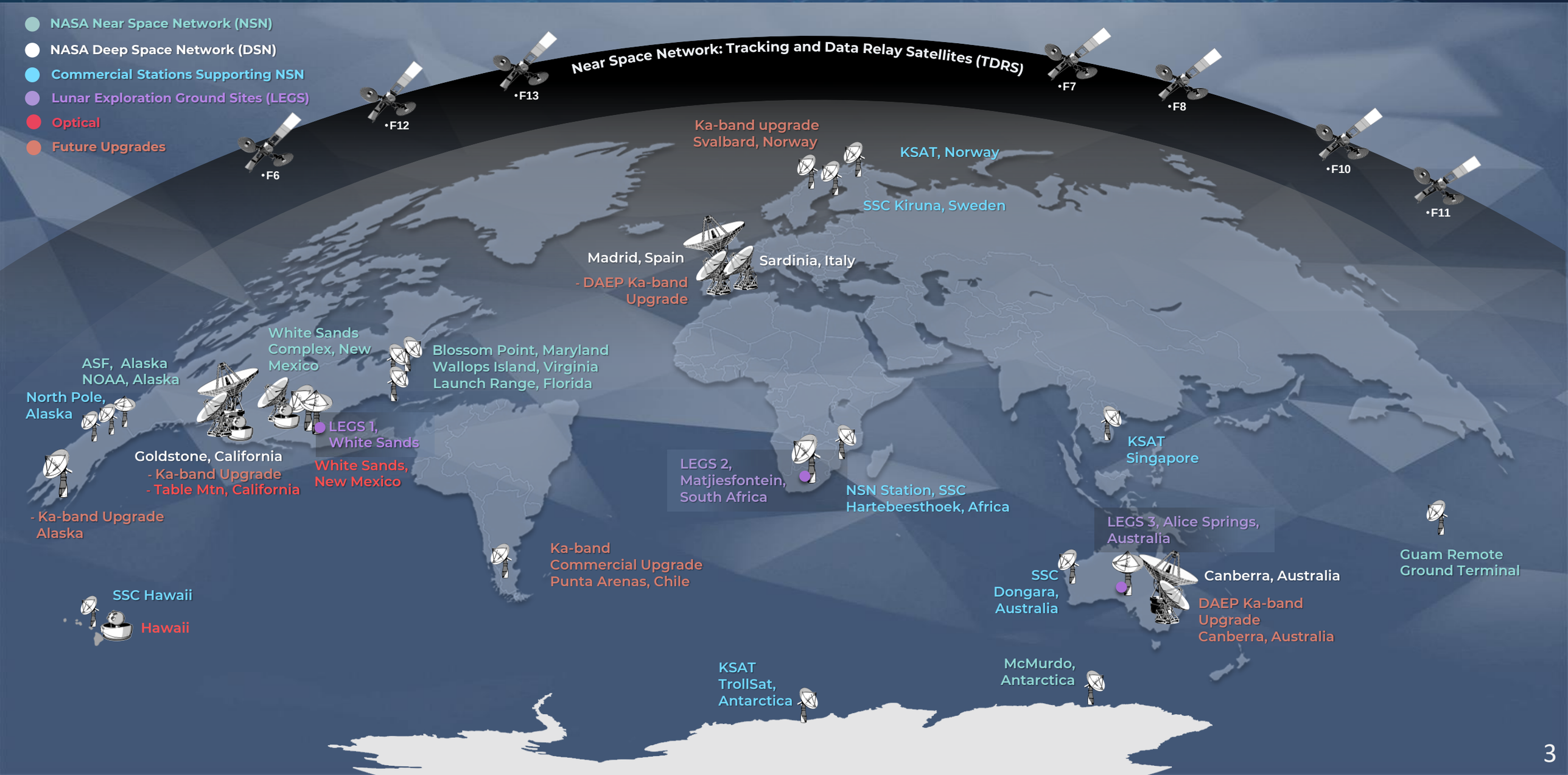
- DLEU In-Progress and Upcoming
  - Antenna upgrades
  - Dichroic mirrors
  - LDPC Decoding and High Rate Low Latency Data Delivery
- Concluding Thoughts

NASA's Communications Networks



Deep Space Network Users and Components

Canberra Deep Space Communications Complex, Australia

Goldstone Deep Space Communications Complex, California

Madrid Deep Space Communications Complex, Spain

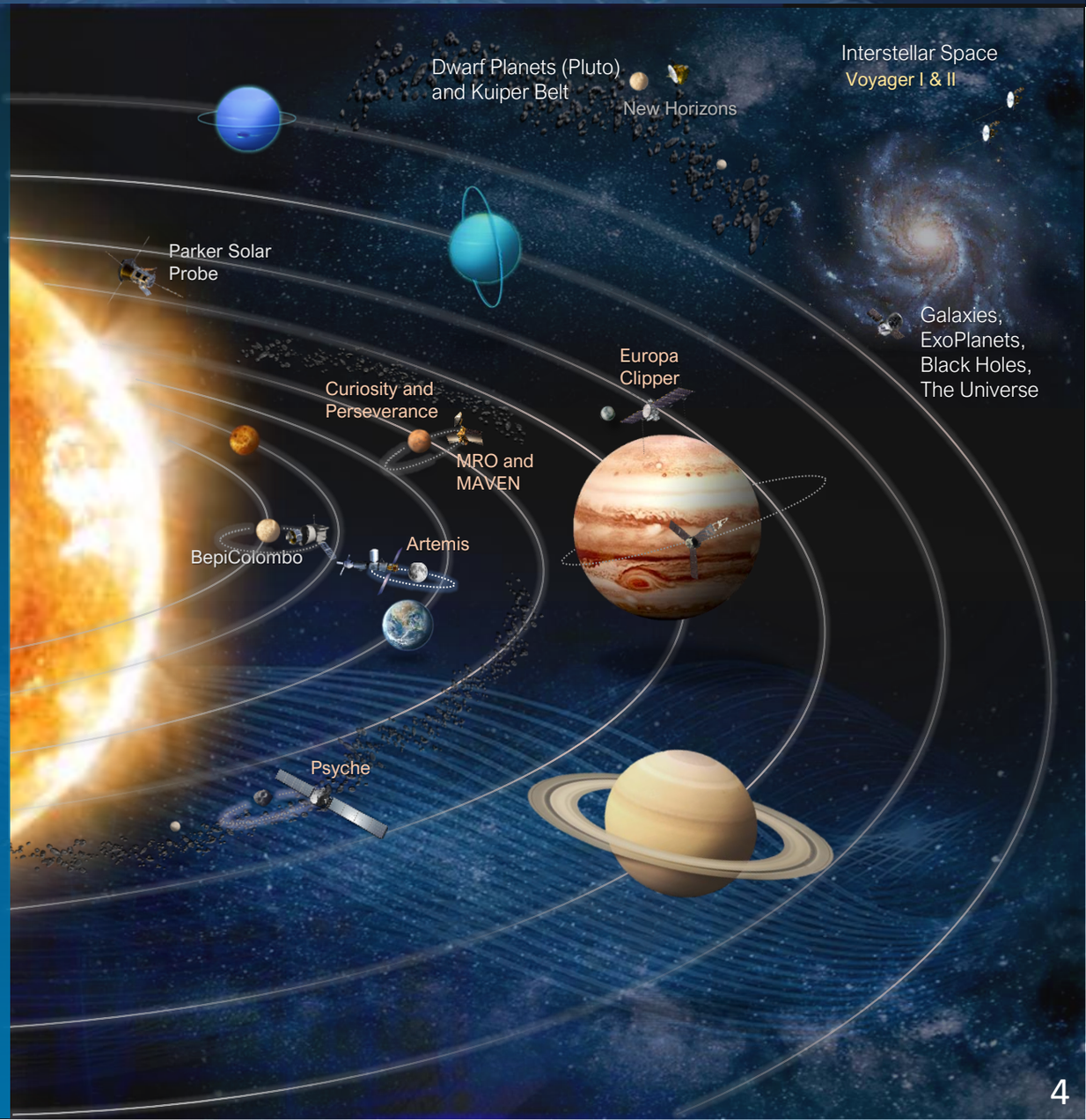
The DSN's prime responsibility is telecommunications for NASA missions, but its also supports many international spacecraft as well as scientific investigations through radio astronomy, radio science, and radar activities.

Network

- Established in December 1963 to provide a communications infrastructure for all of NASA's robotic missions beyond Low Earth Orbit (LEO)
- Consists of three deep-space communications facilities placed approximately 120 degrees apart, hosting 34- and 70-m antennas
- Operates, maintains, and upgrades the 3 tracking complexes around the world, along with centralized operation at Jet Propulsion Laboratory (JPL)

DSN Missions

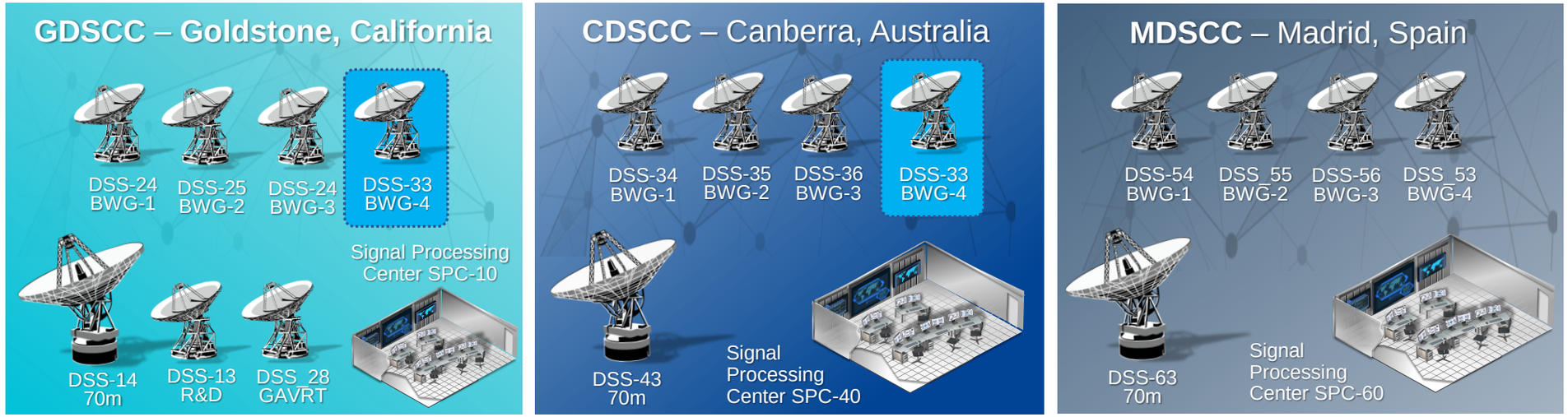
- DSN was designed to communicate with spacecraft located 16,000 km (10,000 miles) from Earth to beyond the edge of the solar system



Antennas and Frequencies

Legend

Future Antennas



Three DSN development and test facilities in addition to main sites:

- DTF-21 in California
- Compatibility Test Trailer CTT-22
- Merritt Island Launch Area (MIL-71) at Kennedy Space Center.

DSN complies with Space Frequency Coordination Group (SFCG) recommendations to supports the near Earth and deep space S-, X-, and Ka-bands

Current Data Rates

- Return Service: 10 bps-600 Mbps
- Forward Service: 7.8 bps-25 Mbps

Service Hours (FY22)

- DSN (Direct-to-Earth): 91,316 hours

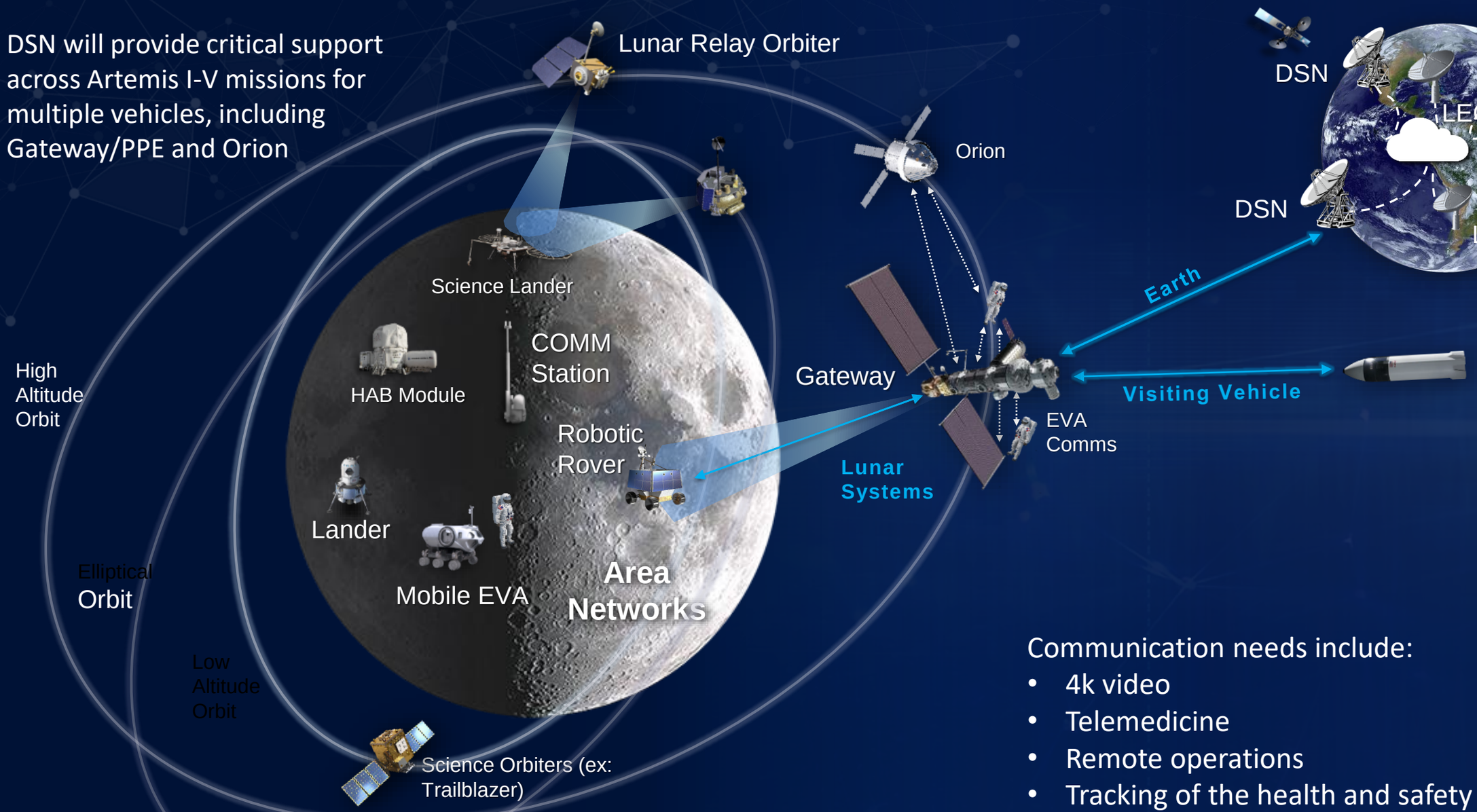
Orbits

- Geosynchronous Earth Orbit (GEO)
- Lunar/Lagrange
- Extra-Lunar/ Planetary

Freq. Band	S Up	S Down	X Up	X Down	Ka Up	Ka Down
Deep Space	2.11-2.12	2.29-2.3	7.145-7.19	8.4-8.45	34.2-34.7	31.8-32.3
Near Earth	2.025-2.11	2.2-2.29	7.19-7.235	8.45-8.5	25.5-27.0	22.55-23.15

Notional View of Artemis

DSN will provide critical support across Artemis I-V missions for multiple vehicles, including Gateway/PPE and Orion



Communication needs include:

- 4k video
- Telemedicine
- Remote operations
- Tracking of the health and safety of astronauts

DSN Lunar Exploration Upgrades

Upgrades to DSN's 34-m subnet represent a low-risk option to help meet Artemis program and Lunar science needs

Modifications will be made to two antennas at each DSN complex – total of six antennas

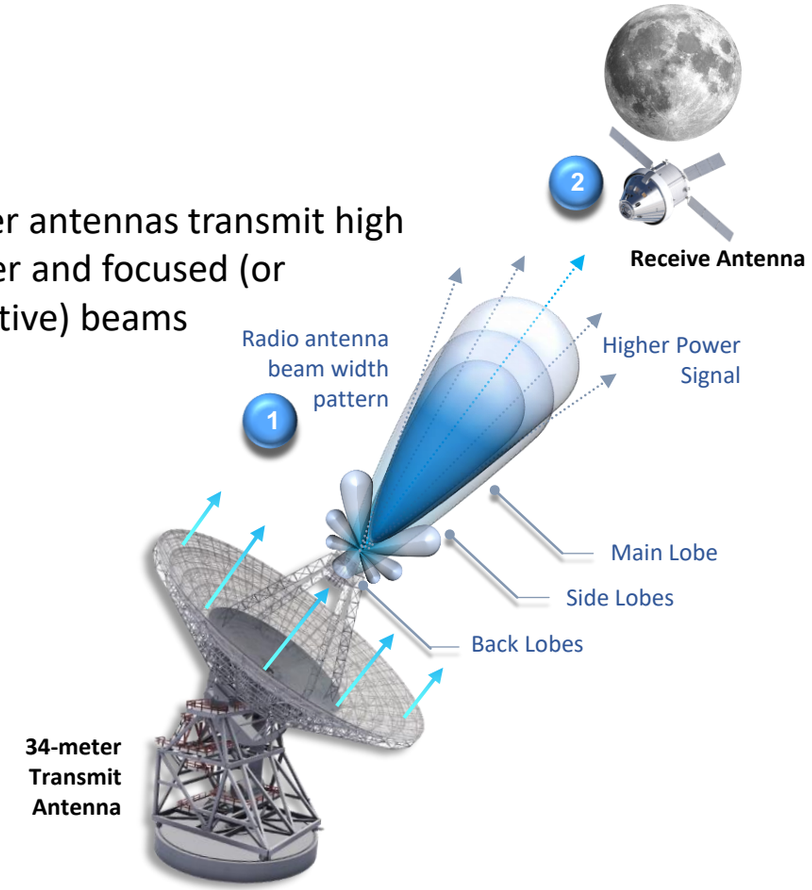
- **Simultaneous Operations**
  - **S** + **Ka-band** or **X** + **Ka-band**
  - Simultaneous Ka-band ↑↓
- **LOW** Latency data processing >150Mbps
- **HIGHER DATA RATES**

	Ka-band	**X-band**
	>100Mbps ↓	>2Mbps ↓
	>20Mbps ↑	>5Mbps ↑

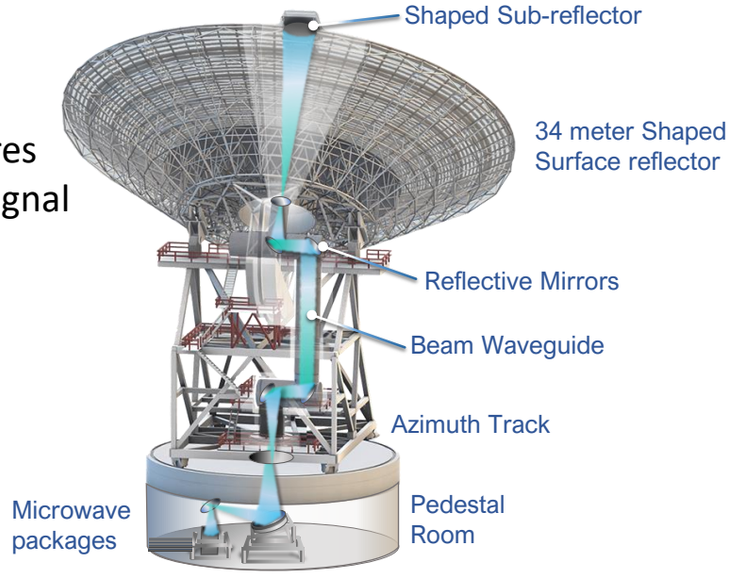
Beam Waveguide Antennas

- Parabolic antenna used here for illustrative purposes
- A ‘small’ signal fed into antenna feed in front of the big dish
- The ‘small’ signal gets amplified by large dish reflector

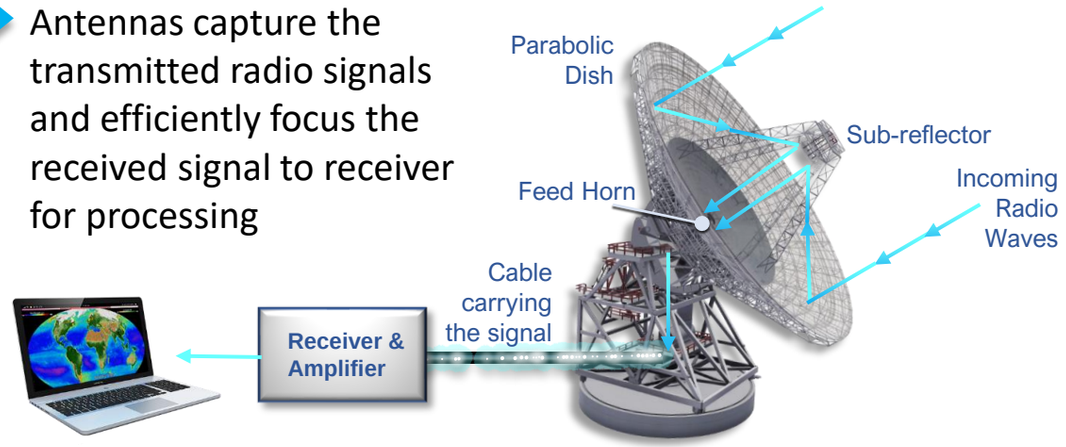
01 Larger antennas transmit high power and focused (or directive) beams



02 Antennas beam waveguide captures the transmitted signal



03 Antennas capture the transmitted radio signals and efficiently focus the received signal to receiver for processing



Simultaneous Operations (1)

Effort to meet the objective includes:

Increase power – add 250W capability to the near-Earth K-band (22.5 GHz) uplink

- Applicable to six antennas across the three DSN sites
- Also added to test facilities: DTF-21, CTT-22, MIL-71

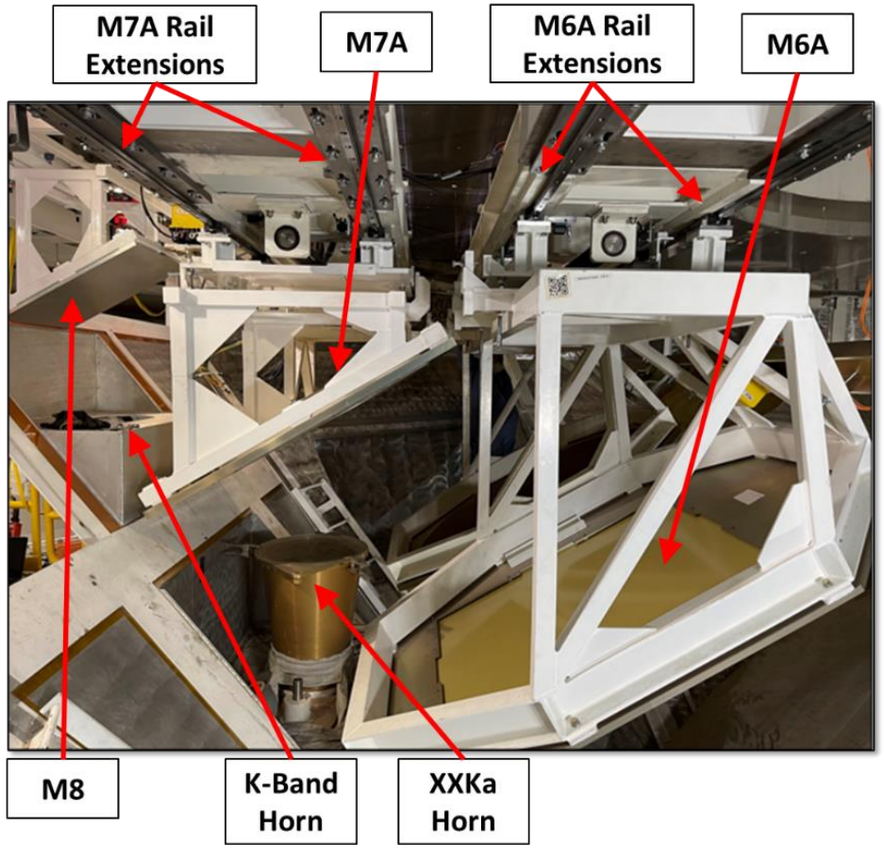
Enable simultaneous X-/KX-/K-band uplinks or simultaneous S-/K-band uplinks

- K-band uplink added as second uplink system
- Configuration changes of the dichroic mirrors
  - > M6A mirror redesigned to provide 22.5 GHz pass through
  - > Two mirrors swapped in (6A and 6B)
  - > M7A mirror designed to reflect X-band and pass 22.5 & 26 GHz
  - > Mounting rails extended to support interchanging mirrors

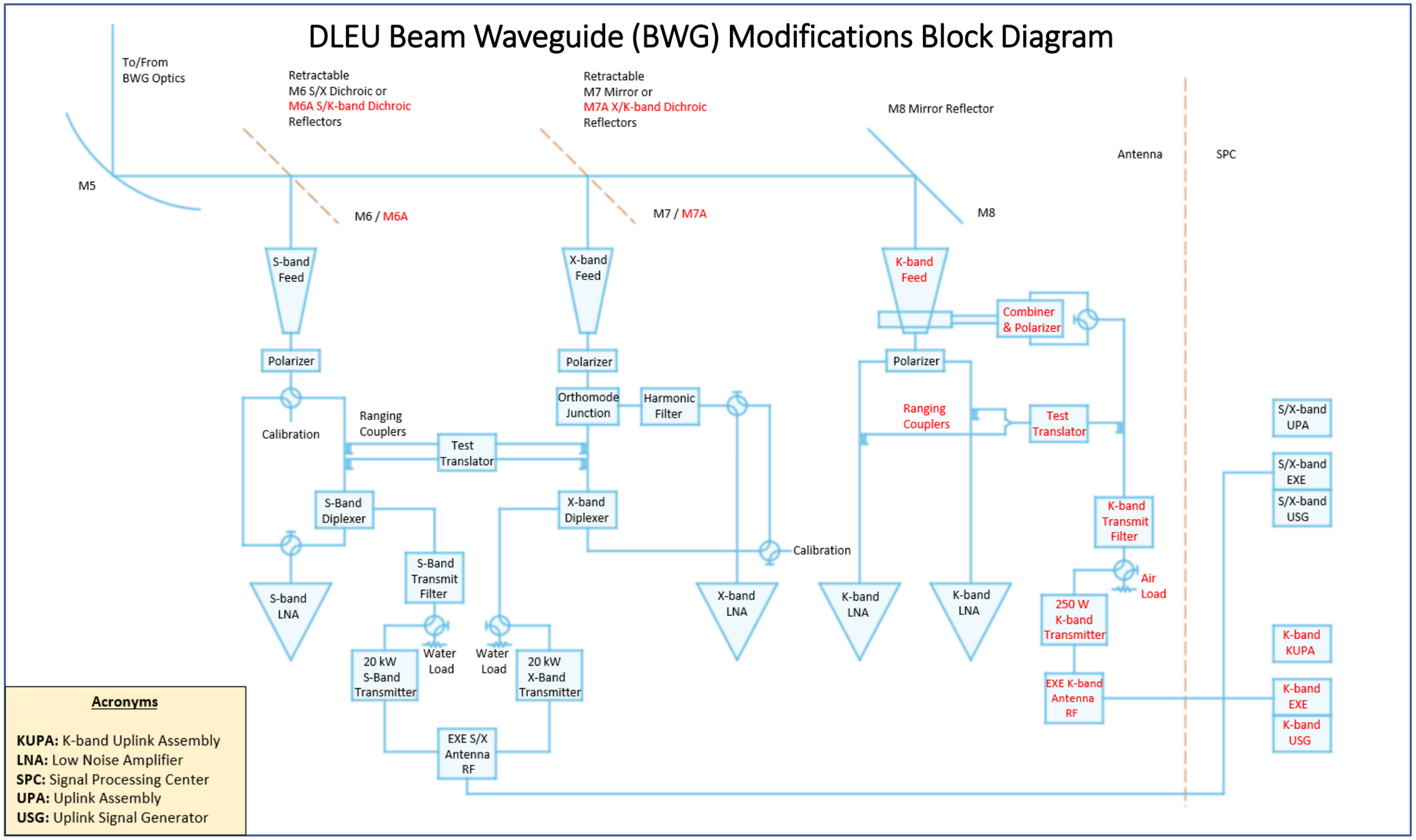
Increase data rate capability

- 20 Mbps (coded) for K-band
- 10 Mbps (coded) X-band
- Exciter modulation capability is common for all exciters, so 20 Mbps will be available at all bands (spectrum constraints may not allow full usage at all bands)

Add capability for filtered OQPSK modulation



Simultaneous Operations (2)



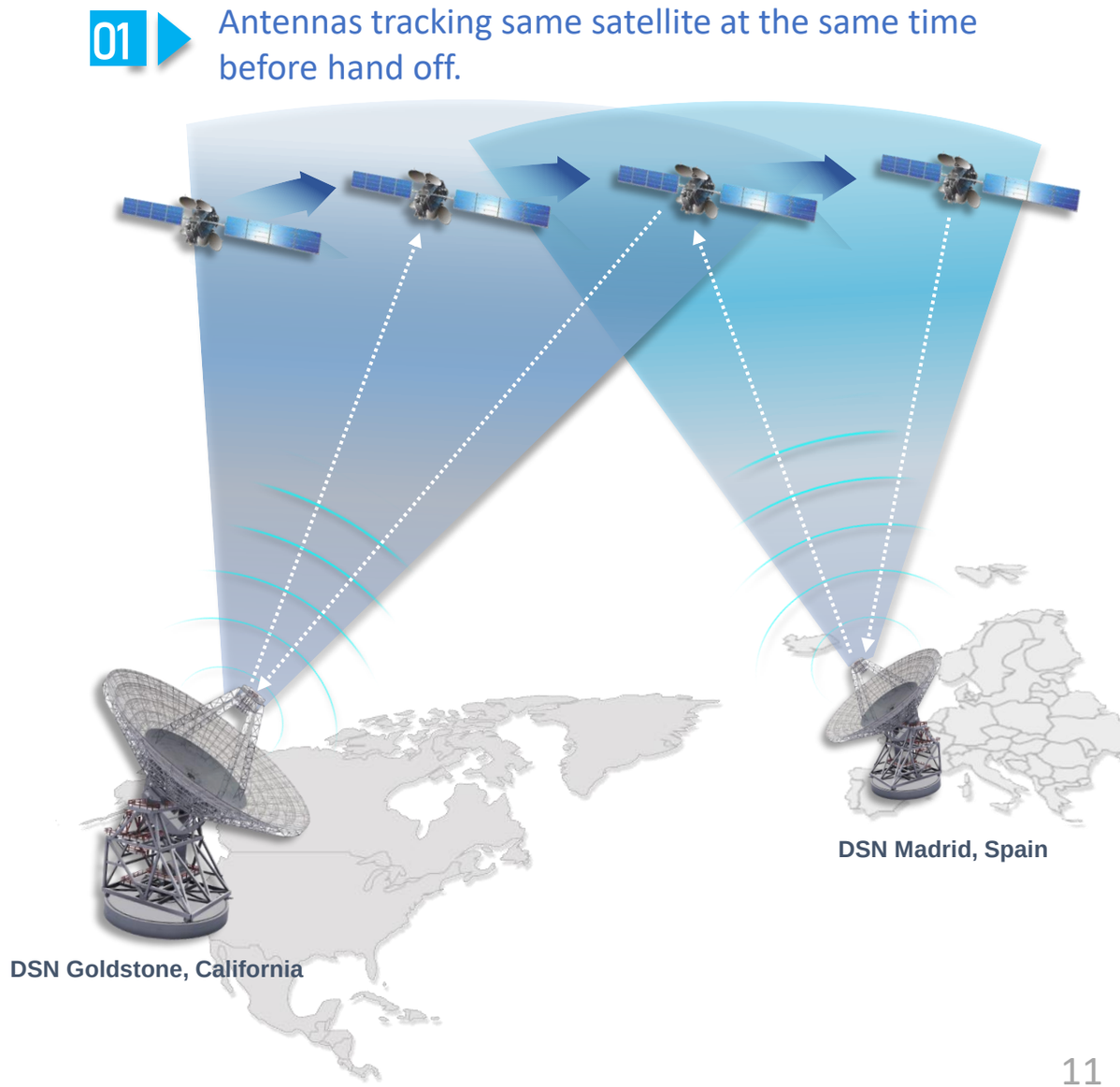
Low Latency Data Processing

Providing 150 Mbps aggregate timely (low latency) data delivery is more than a factor of ten increase in the current system's requirements / capability

- Needs to handle the complex overlap period, when spacecraft are in view and tracked by two sites

Effort to meet the objective includes:

- Modification of the Data Capture and Delivery subsystem (DCD)
- Modifications to other data handling subsystems (e.g., SLE gateway)
- Assumptions:
  - > High-rate streams (> 1 Mbps) will use the large frames (16k bits)
  - > Spacecraft will use Virtual Channels to separate low latency and high latency data
- Complete in time for Artemis Power Propulsion Element (PPE) launch



Higher Data Rates

Effort to meet the objective includes:

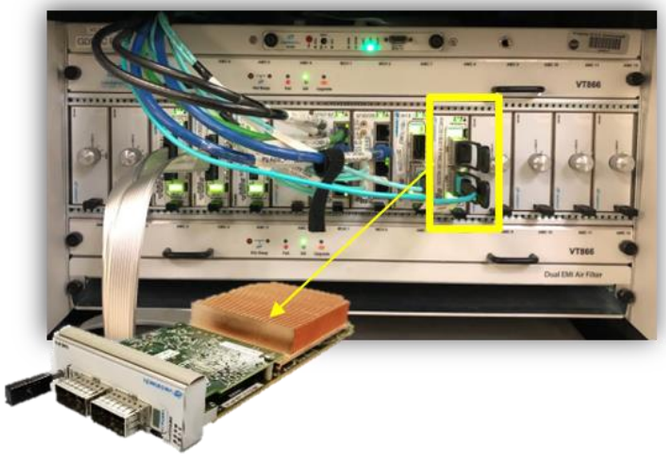
Add 150 Mbps LDPC decoding to the High-Rate Common Platform (HRCP) receiver

- HRCP does 300 Msps symbol tracking and 150 Mbps Convolutional / Reed-Solomon decoding
- Integrating the LDPC decoding does not affect the symbol loop, or the frame delivery to the data transport, since the bit and symbol rates and frame sizes are within its existing requirements
- Requires additional FPGA boards to house the LDPC decoder elements

Provide two channels for each antenna with near Earth K-band downlink – total of four channels per complex

Test signal capability upgrade

Vadatech VT866 uTCA Chassis at GDSCC with HRT card



Summary / Closing

SCaN is committed to understanding future mission requirements and demand

Drives informed decisions about network improvements

To support new lunar missions, DSN is making upgrades

- Higher data rates
- Faster delivery

Five of six antennas are on schedule to be complete prior to Artemis III mission -- the first mission in the campaign to return humans to the surface

SCaN

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Philip Baldwin – Acting Deputy Associate Administrator for the Space Communications and Navigation Program, NASA

Email: philip.j.baldwin@nasa.gov

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